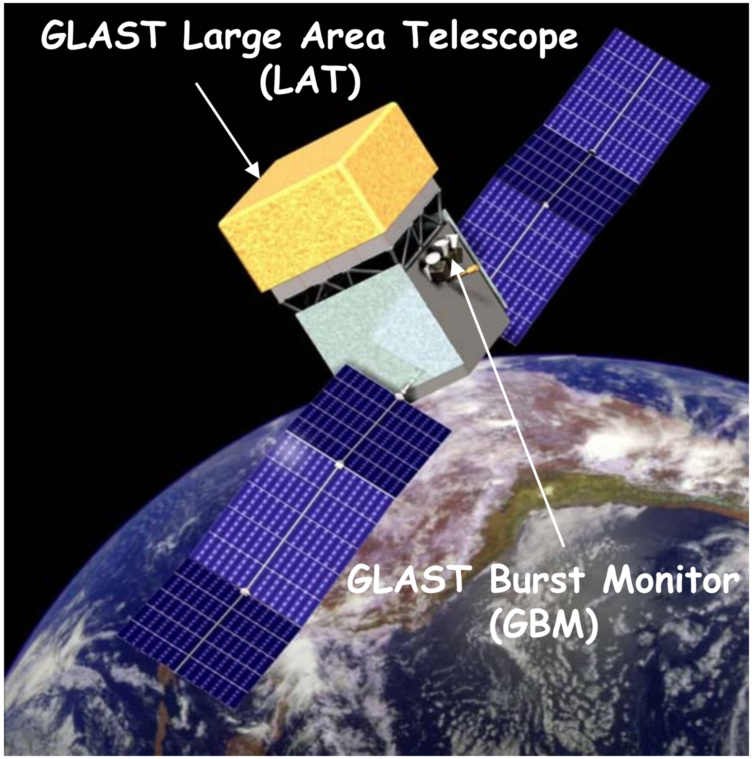

GLAST

GeV Astronomy in a Multiwavelength Context

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GLAST Large Area Telescope Collaboration
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Special thanks to Steve Ritz and Seth Digel for studies of LAT capabilities

Outline

- PAST: Multiwavelength motivation from CGRO
- PRESENT: GLAST design and expected performance
- FUTURE: Operating plans for GLAST

PAST:

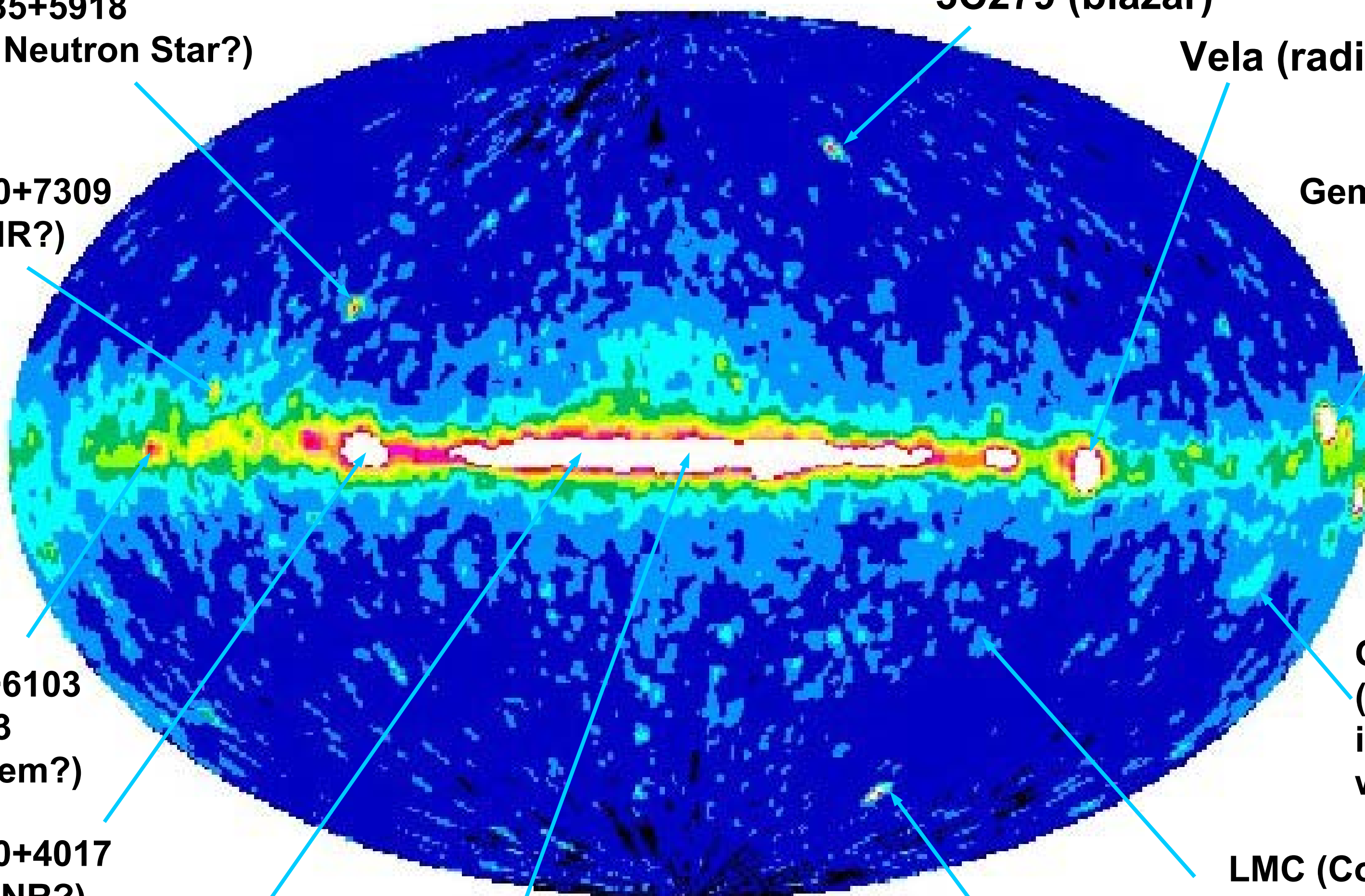
What CGRO taught us about the gamma-ray sky, some science topics, and the need for multiwavelength observations.

Gamma-ray Sources: Inherently Multiwavelength

In the MeV range and above, sources are non-thermal
$\Rightarrow$ produced by interactions of energetic particles

- Nature rarely produces monoenergetic particle beams. Broad range of particle energies leads to a broad range of photon energies.
  - Example: π^o production
- Charged particles rarely interact by only one process. Different processes radiate in different energy bands.
  - Example: synchrotron-Compton processes
- High-energy particles, as they lose energy, can radiate in lower-energy bands.
  - Contrast: nonthermal X-ray source can have high-energy cutoff

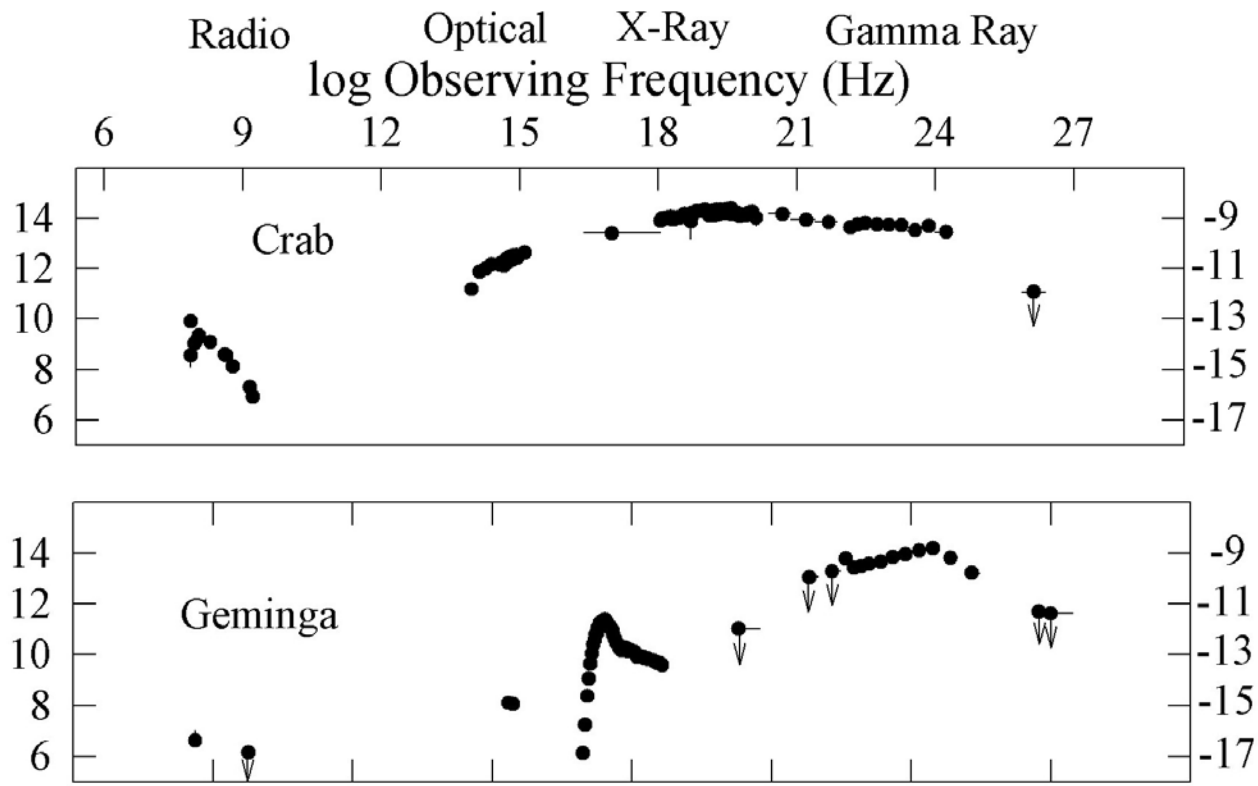
EGRET All Sky Map (>1 GeV)



Pulsars – Rotating Neutron Stars

Science Topics

- Neutron star population studies.
- Location and nature of particle acceleration and interaction (model testing).
- Physics in extreme magnetic and electric fields.
- Matter state at high densities.
- Relativistic effects.

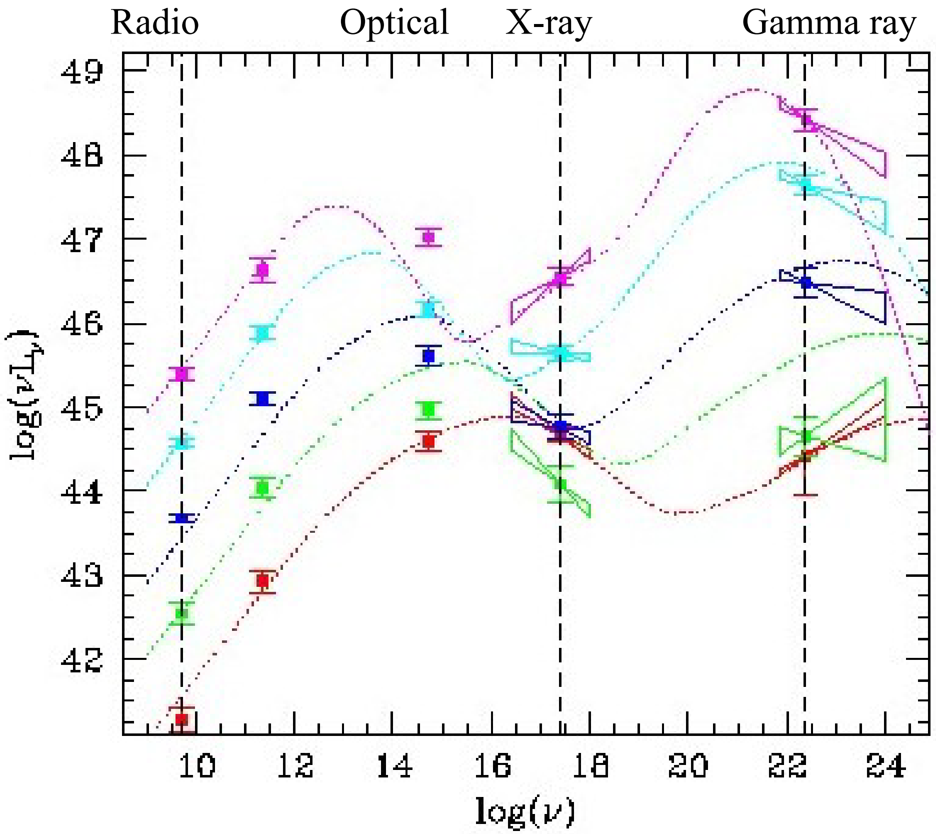


Except for the pulsations themselves, time variability is not significant for pulsars. Simultaneous multiwavelength observations are not essential.

AGN – Multiwavelength Variety

Science Topics

- Location and nature of particle acceleration and interaction in jets.
- Confirmation of unified models.
- Cosmological probes using high-energy cutoff due to absorption by Extragalactic Background Light.
- Contribution to the diffuse background.

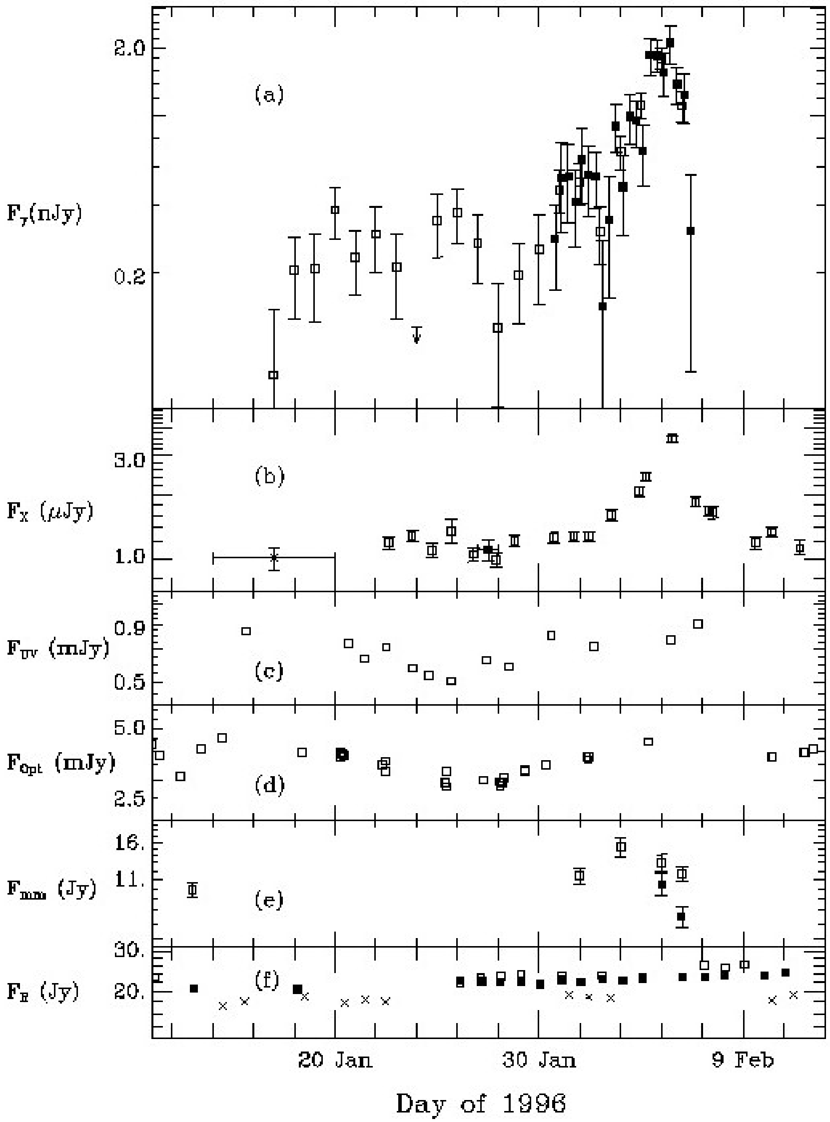


Fossati's summary of blazar Spectral Energy Distributions

Due to variability on short time scales, AGN require simultaneous multiwavelength observations for maximum scientific return.

AGN – Multiwavelength Variability

- Strength and phasing of flaring at different wavelengths is a powerful tool for modeling emission.
- Also need observations before and after a flare to be sure it is the same flare.
- Test universality of the idea that high states have flatter spectra.



3C279

Gamma rays

X-rays

UV

Optical

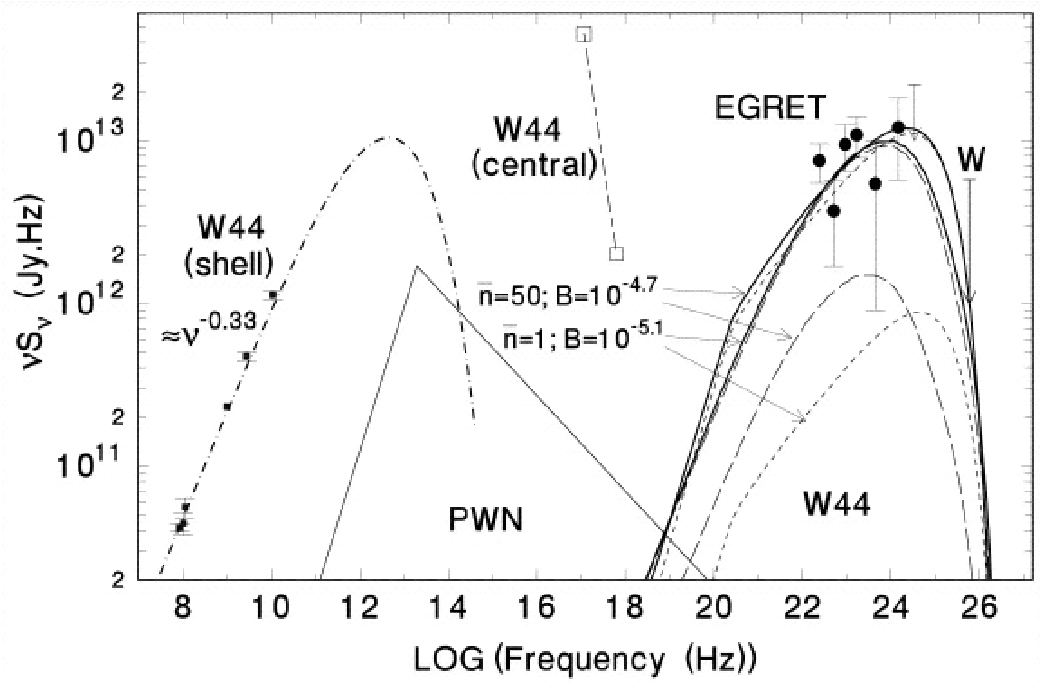
IR

Radio

Supernova Remnants – Origin of Cosmic Rays?

Science Topics

- Electron v. proton acceleration in SNR.
- Interactions with interstellar medium.
- Upper limit of SNR acceleration of cosmic rays.



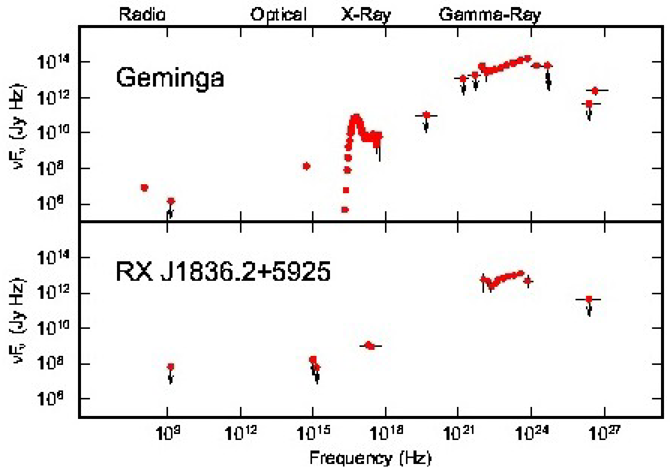
Multi-component model of SNR W44 by De Jager and Mastichiadis (1997). Components include synchrotron, thermal X-ray, pulsar wind nebula, relativistic bremsstrahlung, and inverse Compton.

Time scale for variability is long; therefore simultaneity is not critical for multiwavelength observations.

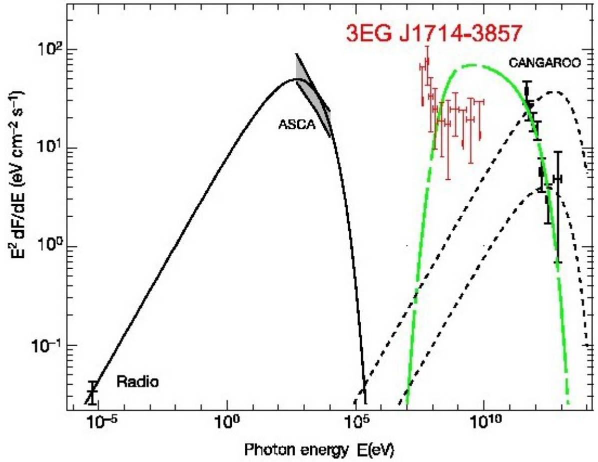
Unidentified Sources

Science Topics

- Discovery science.
- New sources or new insight about known objects.
- Nature of non-blazar transients.



Spectrum of 3EG J1835+5918 compared to that of Geminga, indicating a probable isolated neutron star (Halpern et al., Reimer et al.)



Spectrum of 3EG J1714-3857/SNR RXJ1713-3946. With the limited multiwavelength coverage, no simple model explains the source (Reimer and Pohl).

For transients or other variable unidentified gamma-ray sources, having simultaneous observations may be the <u>only</u> viable means of positive identification.

Some Lessons Learned from CGRO

No Real Surprises Here

- Observers at other wavelengths seem very helpful with “service observations”, as long as the observing time needed is relatively small.
- Organizing a true multiwavelength campaign, especially for extended observations, is VERY difficult.
- Relying on a few “friends” to carry out coordinated observations is risky (ground conditions vary).
- We were most successful in just announcing a target of interest to a large group and then seeing who was able to collect data.
- AGN flares seemed to be more easily seen first in gamma rays; these could prove to be a useful trigger for a coordinated campaign.
- Unidentified gamma-ray sources are far less interesting than known objects to observers at other wavelengths (largely due to position uncertainties).

PRESENT:

GLAST capabilities in relation to these multiwavelength science objectives.

GLAST – Basic Information

<u>**GLAST: Gamma-ray Large Area Space Telescope is the observatory, not the instruments.**</u>

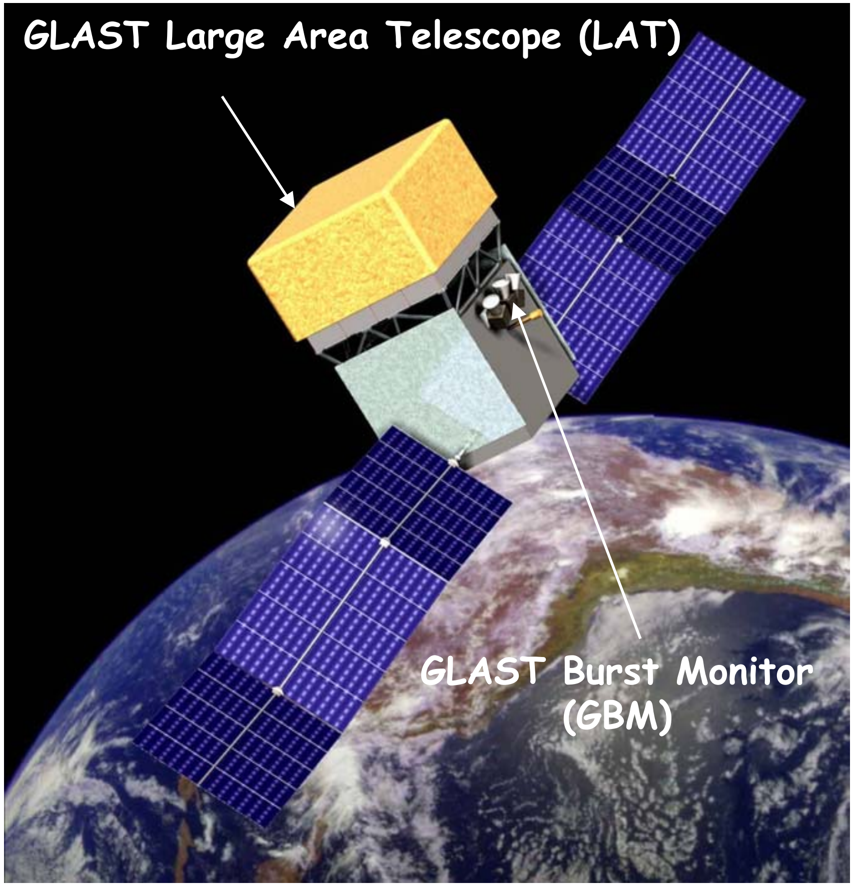
<u>**Two GLAST instruments**</u>**:**

LAT: 20 MeV – >300 GeV
(LAT was originally called GLAST by itself)

GBM: 10 keV – 25 MeV

Launch: September 2006

Lifetime: 5 years minimum



GBM Collaboration

National Space Science & Technology Center

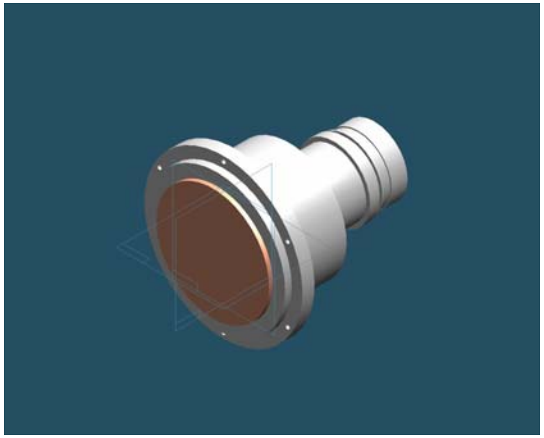
University of Alabama in Huntsville	NASA Marshall Space Flight Center	Max-Planck-Institut für extraterrestrische Physik
Michael Briggs William Paciesas Robert Preece	Charles Meegan (PI) Gerald Fishman Chryssa Kouveliotou	Giselher Lichti (Co-PI) Andreas von Keinlin Volker Schönfelder Roland Diehl

On-board processing, flight software, systems engineering, analysis software, and management

Detectors, power supplies, calibration, and analysis software

GBM Instrument Design: Major Components

12 Sodium Iodide (NaI) Scintillation Detectors



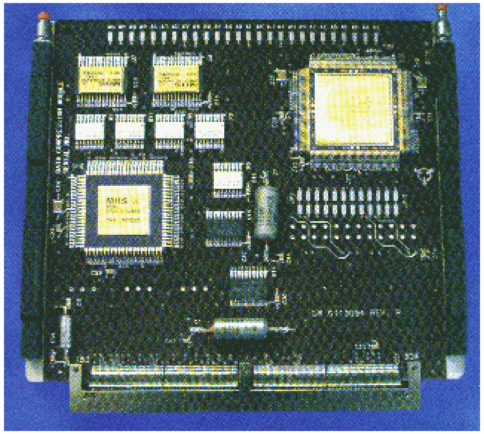
Characteristics

- 5-inch diameter, 0.5-inch thick
- One 5-inch diameter PMT per Det.
- Placement to maximize FoV
- Thin beryllium entrance window
- Energy range: ~5 keV to 1 MeV

Major Purposes

- Provide low-energy spectral coverage in the typical GRB energy regime over a wide FoV
- Provide rough burst locations over a wide FoV

Data Processing Unit (DPU)



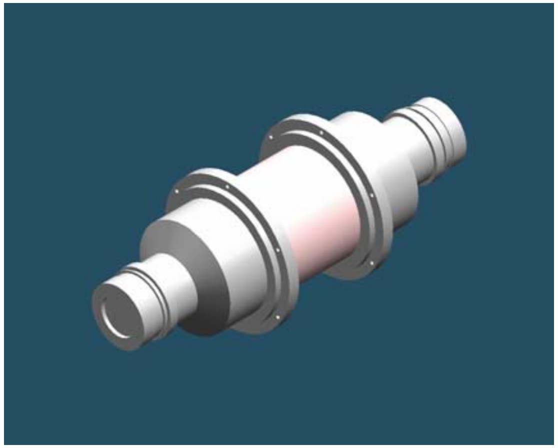
Characteristics

- Analog data acquisition electronics for detector signals
- CPU for data packaging/processing

Major Purposes

- Central system for instrument command, control, data processing
- Flexible burst trigger algorithm(s)
- Automatic detector/PMT gain control
- Compute on-board burst locations
- Issue r/t burst alert messages

2 Bismuth Germanate (BGO) Scintillation Detectors



Characteristics

- 5-inch diameter, 5-inch thick
- High-Z, high-density
- Two 5-inch diameter PMTs per Det.
- Energy range: ~150 keV to 30 MeV

Major Purpose

- Provide high-energy spectral coverage to overlap LAT range over a wide FoV

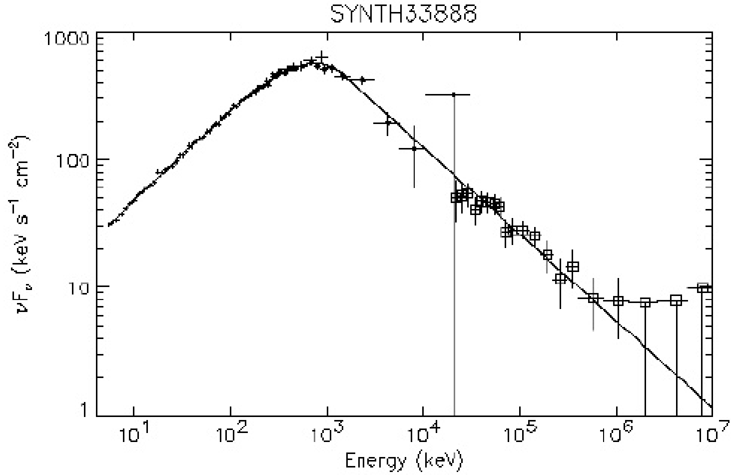
GBM (PI: Meegan)

- **provides spectra for bursts from 10 keV to 30 MeV, connecting frontier LAT high-energy measurements with more familiar energy domain;**

Simulated GBM and LAT response to time-integrated flux from bright GRB 940217

Spectral model parameters from CGRO wide-band fit

1 NaI (14 º) and 1 BGO (30 º)



- **provides wide sky coverage (8 sr) -- enables autonomous repoint requests for exceptionally bright bursts that occur outside LAT FOV for high-energy afterglow studies (an important question from EGRET);**
- **provides burst alerts to the ground.**

GLAST LAT Collaboration

United States

- California State University at Sonoma
- University of California at Santa Cruz - Santa Cruz Institute of Particle Physics
- Goddard Space Flight Center – Laboratory for High Energy Astrophysics
- Naval Research Laboratory
- Stanford University – Hanson Experimental Physics Laboratory
- Stanford University - Stanford Linear Accelerator Center
- Texas A&M University – Kingsville
- University of Washington
- Washington University, St. Louis

France

- Centre National de la Recherche Scientifique / Institut National de Physique Nucléaire et de Physique des Particules
- Commissariat à l'Energie Atomique / Direction des Sciences de la Matière/ Département d'Astrophysique, de physique des Particules, de physique Nucléaire et de l'Instrumentation Associée

Italy

- Istituto Nazionale di Fisica Nucleare
- Istituto di Fisica Cosmica, CNR (Milan)

Japanese GLAST Collaboration

- Hiroshima University
- Institute for Space and Astronautical Science
- RIKEN

Swedish GLAST Collaboration

- Royal Institute of Technology (KTH)
- Stockholm University

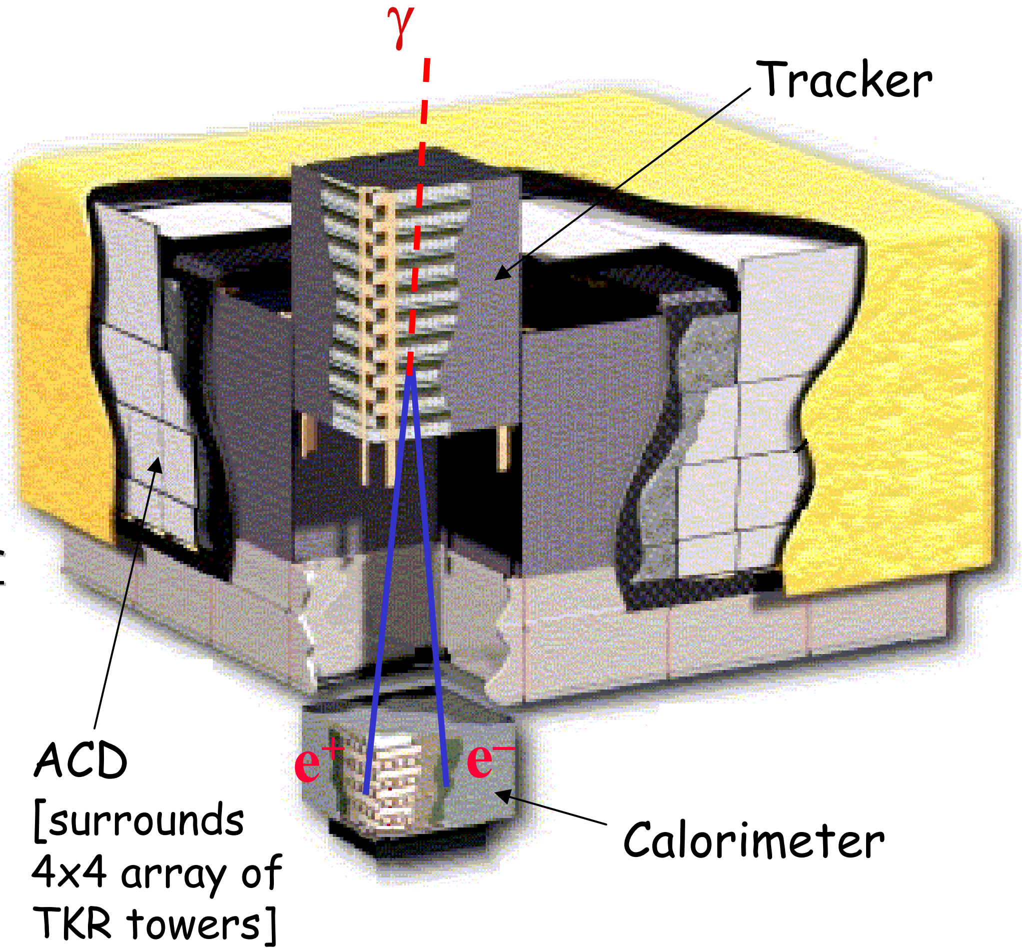
PI: Peter Michelson (Stanford & SLAC)

124 Members (including 60 Affiliated Scientists, plus 16 Postdoctoral Students, and 26 Graduate Students)

LAT Project is a partnership between NASA and DOE, with international contributions from France, Italy, Japan and Sweden. Managed at Stanford Linear Accelerator Center (SLAC).

Overview of LAT

- Precision Si-strip Tracker (TKR)
  18 XY tracking planes. Single-sided silicon strip detectors (228 μm pitch) Measure the photon direction; gamma ID.
- Hodoscopic CsI Calorimeter(CAL)
  Array of 1536 CsI(Tl) crystals in 8 layers. Measure the photon energy; image the shower.
- Segmented Anticoincidence Detector (ACD) 89 plastic scintillator tiles. Reject background of charged cosmic rays; segmentation removes self-veto effects at high energy.
- Electronics System Includes flexible, robust hardware trigger and software filters.



Systems work together to identify and measure the flux of cosmic gamma rays with energy 20 MeV - >300 GeV.

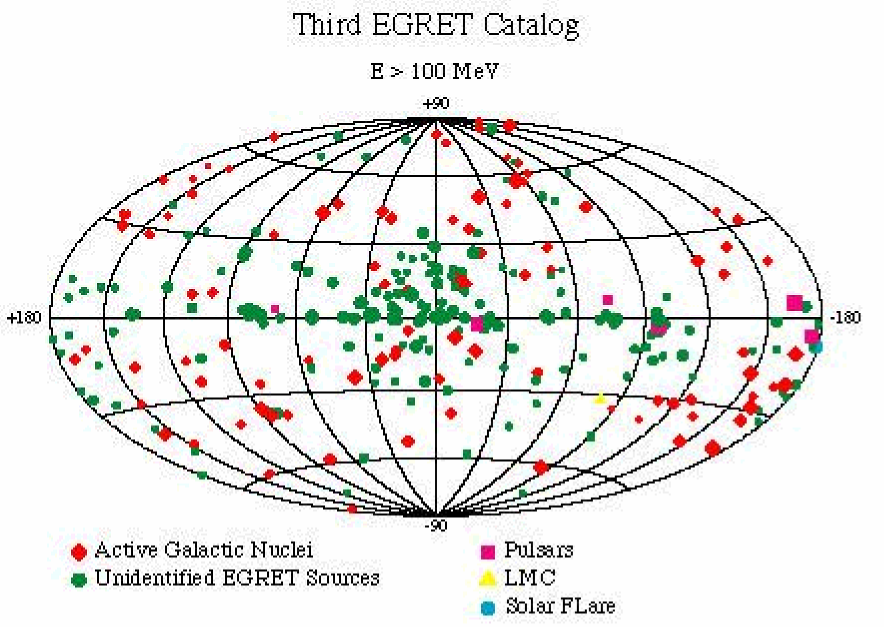
GLAST LAT High Energy Capabilities

- Huge FOV (~20% of sky)
- Broadband (4 decades in energy, including unexplored region > 10 GeV)
- Unprecedented PSF for gamma rays (factor > 3 better than EGRET for E>1 GeV)
- Large effective area (factor > 4 better than EGRET)
- **Results in factor > 30-100 improvement in sensitivity**
- No expendables ⟶ long mission without degradation

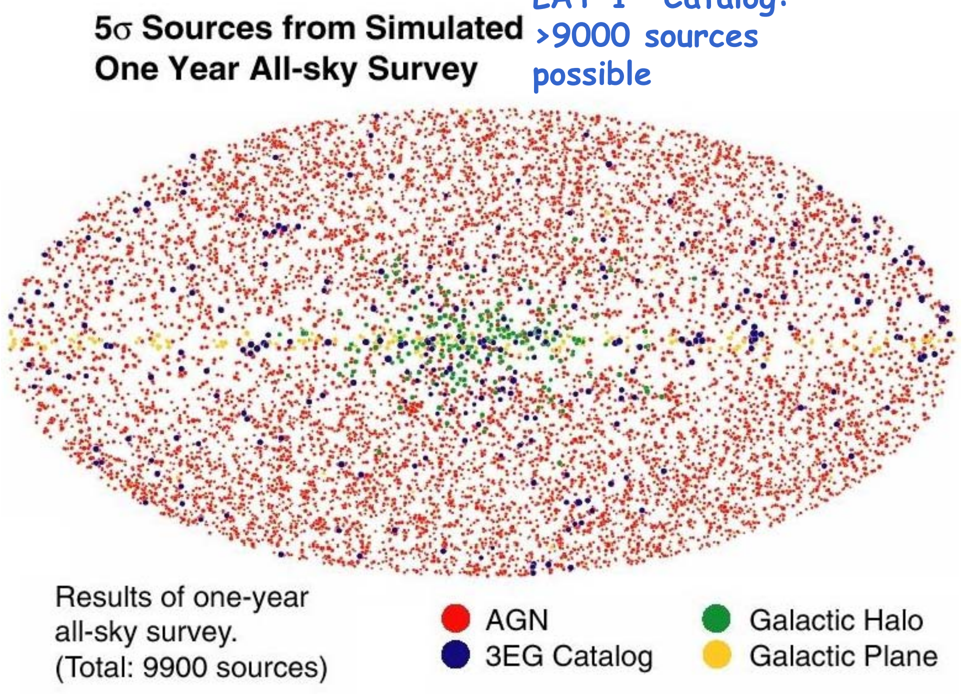
LAT Science Performance Summary

Parameter	SRD Value	Present Design Value
Peak Effective Area (in range 1-10 GeV)	>8000 cm^2	10,000 cm^2 at 10 GeV
Energy Resolution 100 MeV on-axis	<10%	9%
Energy Resolution 10 GeV on-axis	<10%	8%
Energy Resolution 10-300 GeV on-axis	<20%	<15%
Energy Resolution 10-300 GeV off-axis	<6%	<4.5%
PSF 68% 100 MeV on-axis	<3.5°	3.37° (front), 4.64° (total)
PSF 68% 10 GeV on-axis	<0.15°	0.086° (front), 0.115° (total)
PSF 95/68 ratio (100 MeV)	<3	2.1 front, 2.6 back
PSF 55º/normal ratio	<1.7	1.6
Field of View	>2sr	2.4 sr
Background rejection (E>100 MeV)	<10% diffuse	6% diffuse (adjustable)
Point Source Sensitivity(>100MeV)	<6x10^{-9} $cm^{-2}s^{-1}$	3x10^{-9} $cm^{-2}s^{-1}$
Source Location Determination	<0.5 arcmin	<0.4 arcmin
GRB localization	<10 arcmin	5 arcmin

Many More Sources Expected



LAT 1st Catalog:
>9000 sources possible



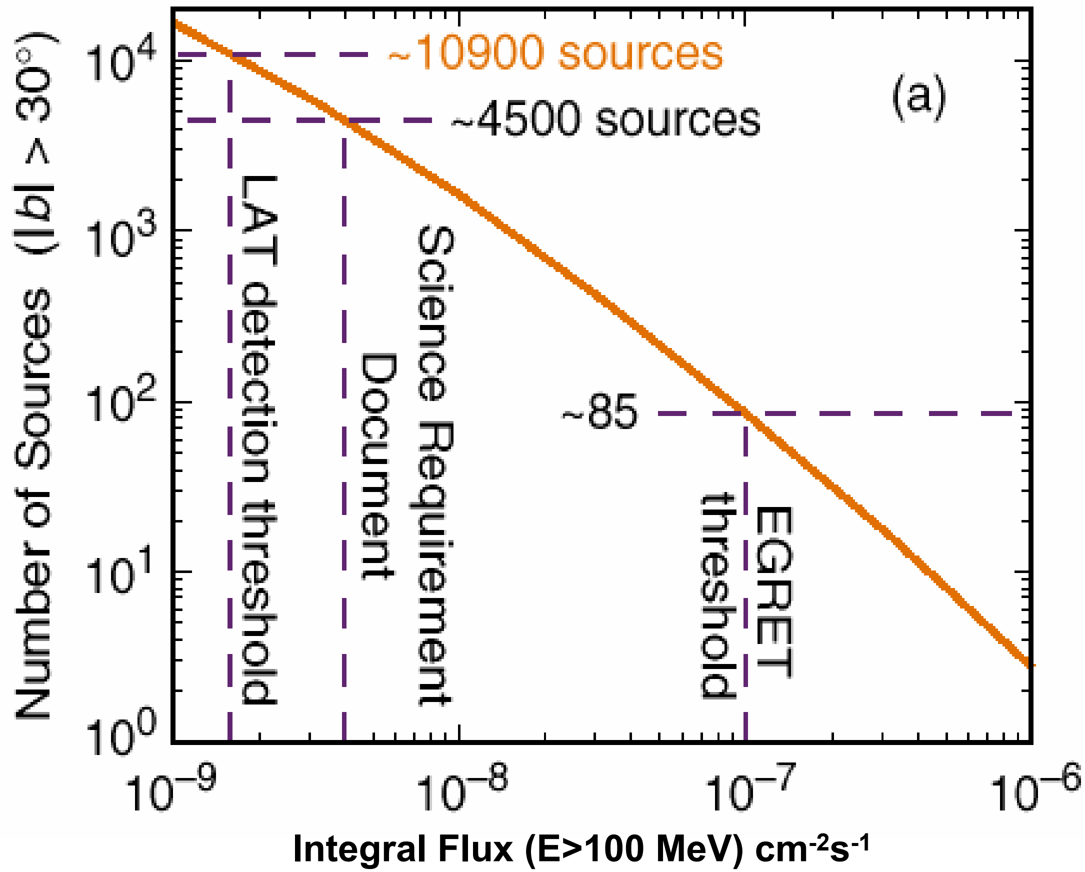
The 271 sources in the third EGRET catalog involved considerable manual processing. The LAT analysis will rely much more heavily on automated processing.

AGN: What GLAST will do

• EGRET detected ~ 70-90 AGN. Extrapolating, GLAST should expect to see dramatically more – many thousands.

• The GLAST energy range is broad, overlapping those of ground-based experiments for good multiwavelength coverage.

• The wide field of view will allow GLAST to monitor AGN for time variability on many scales.



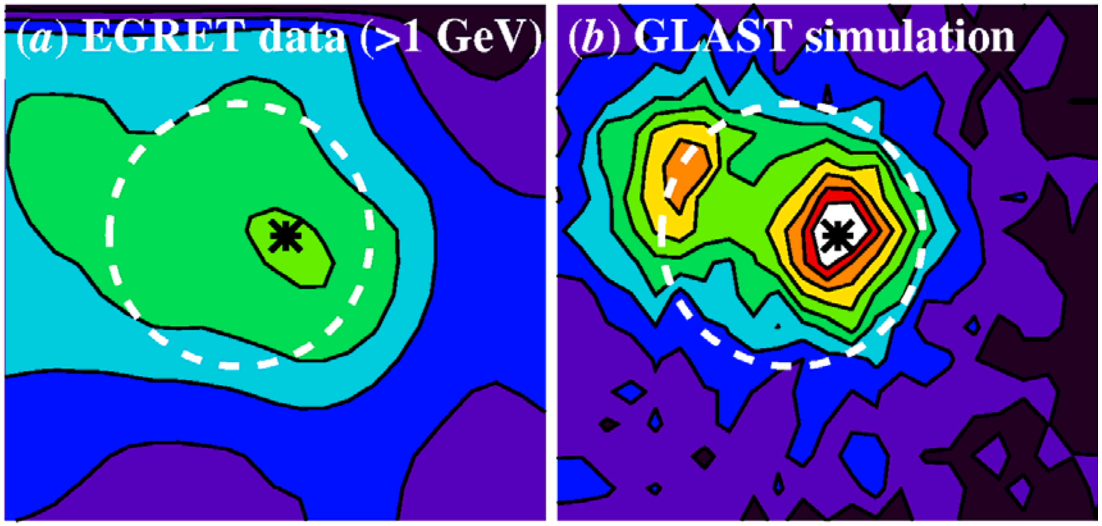
Joining the unique capabilities of GLAST with other detectors will provide a powerful tool.

SNR: Spatial Resolution by GLAST

• For SNR candidates, the LAT sensitivity and resolution will allow mapping to separate extended emission from the SNR from possible pulsar components.

• Energy spectra for the two emission components may also differ.

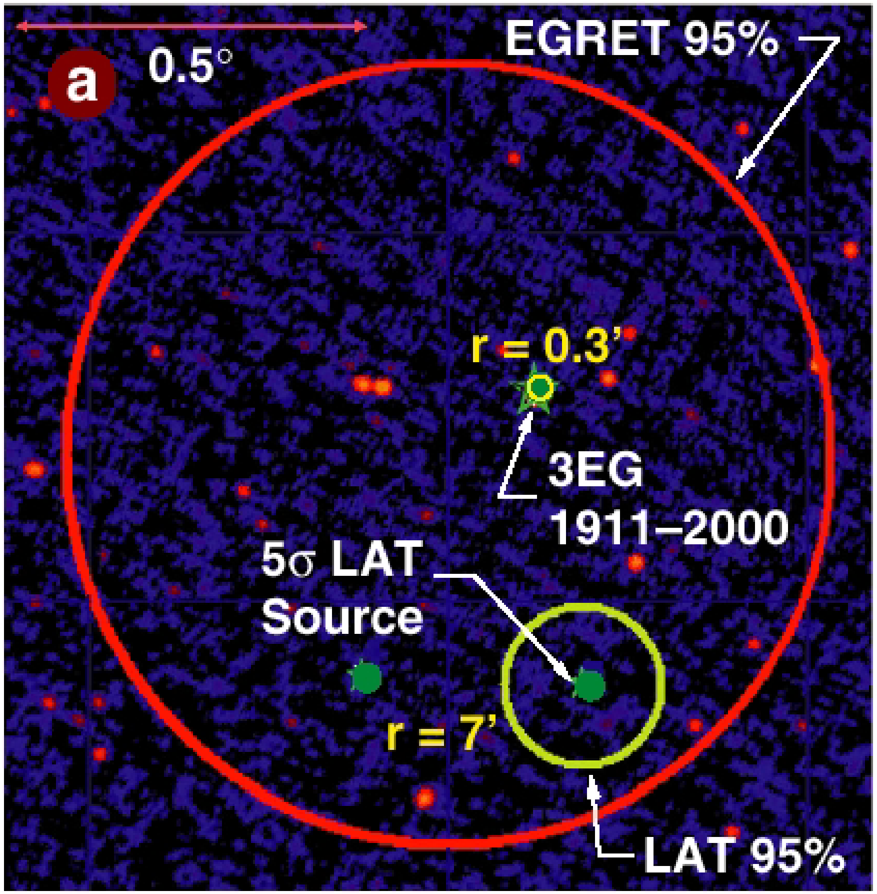
• Resolved images will allow observations at other wavelengths to concentrate on promising directions.



(*a*) Observed (EGRET) and (*b*) simulated LAT (1-yr sky survey) intensity in the vicinity of **γ-Cygni** for energies >1 GeV. The coordinates and scale are the same as in the images of γ-Cygni in the box at left. The dashed circle indicates the radio position of the shell and the asterisk the pulsar candidate proposed by Brazier et al. (1996).

Unidentified Sources – Better Positions

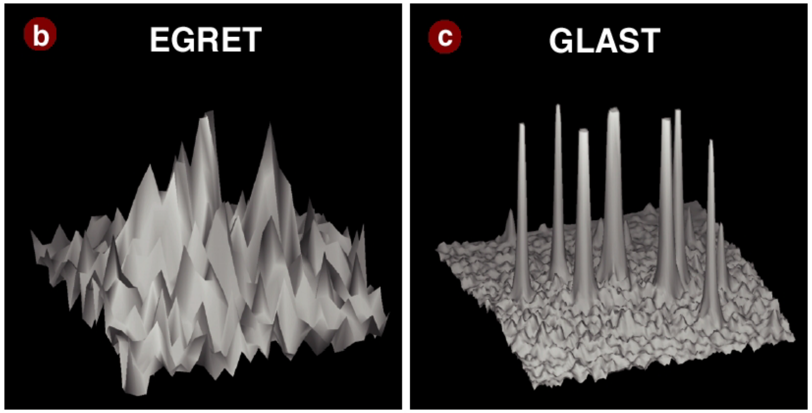
172 of the 271 sources in the EGRET 3rd catalog are "unidentified"



● Rosat or Einstein X-ray Source
● 1.4 GHz VLA Radio Source

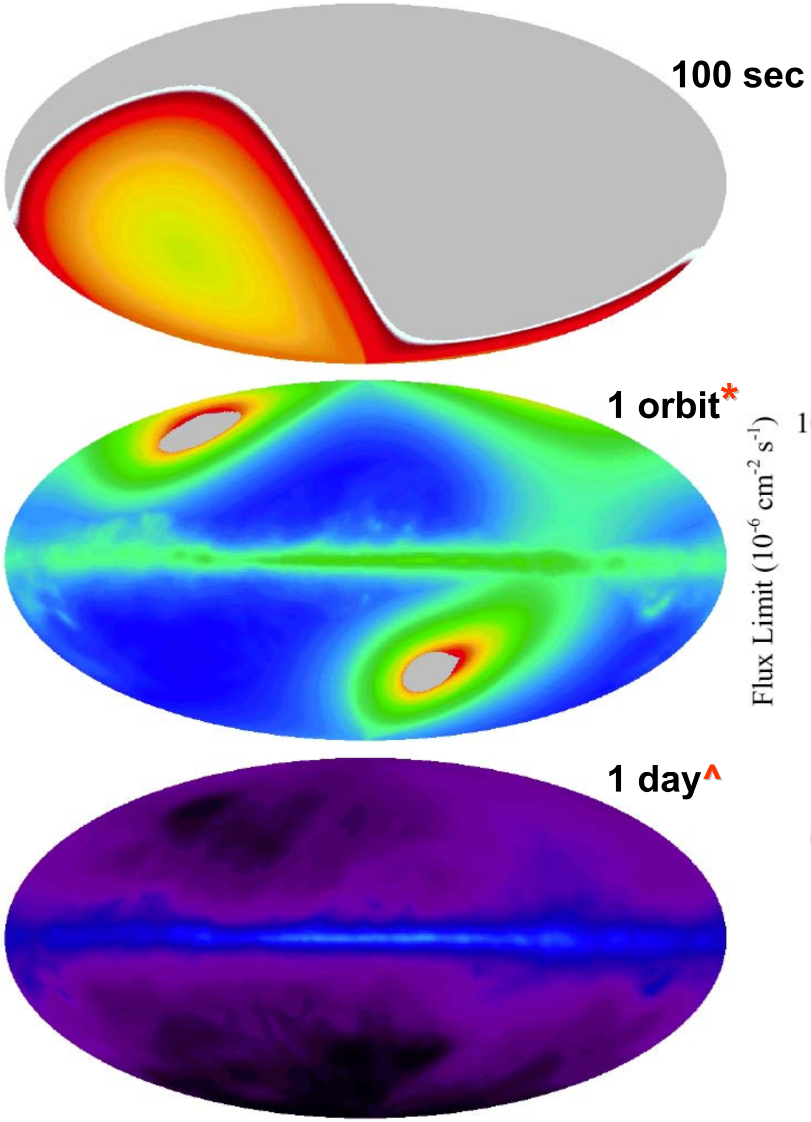
EGRET source position error circles are ~0.5°, resulting in counterpart confusion.

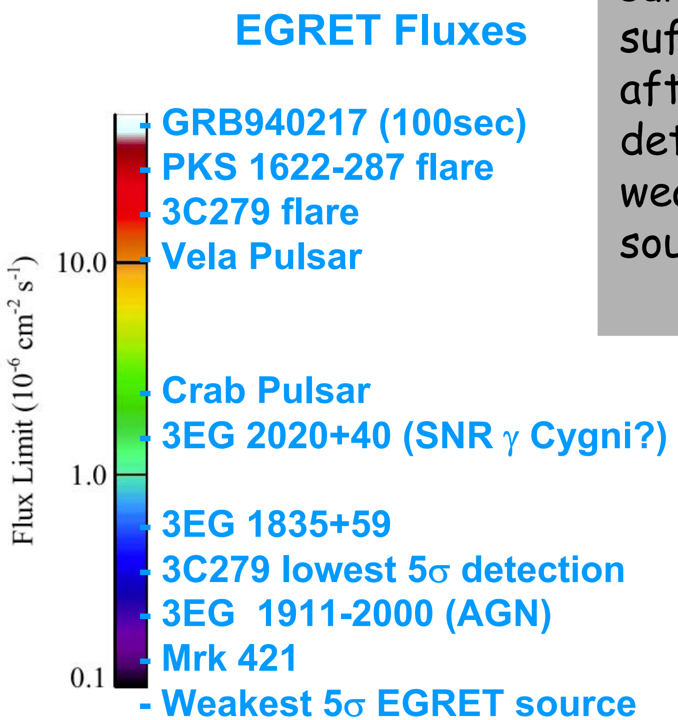
GLAST will provide much more accurate positions, with ~30 arcsec - ~5 arcmin localizations, depending on brightness. Better positions facilitate multiwavelength comparisons.



Cygnus region (15x15 deg)

LAT Sensitivity During All-sky Scan Mode



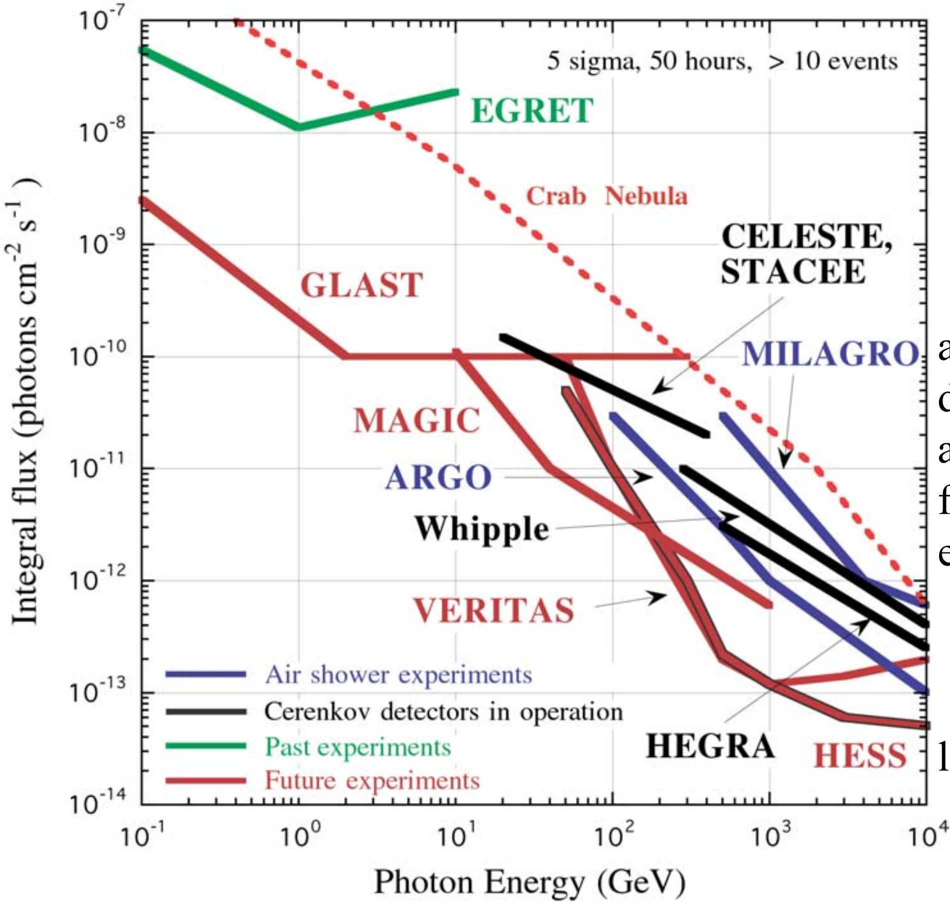


During the all-sky survey, LAT will have sufficient sensitivity after one day to detect (5σ) the weakest EGRET sources.

*zenith-pointed

^"rocking" all-sky scan: alternating orbits point above/below the orbit plane

Gamma-ray Observatories

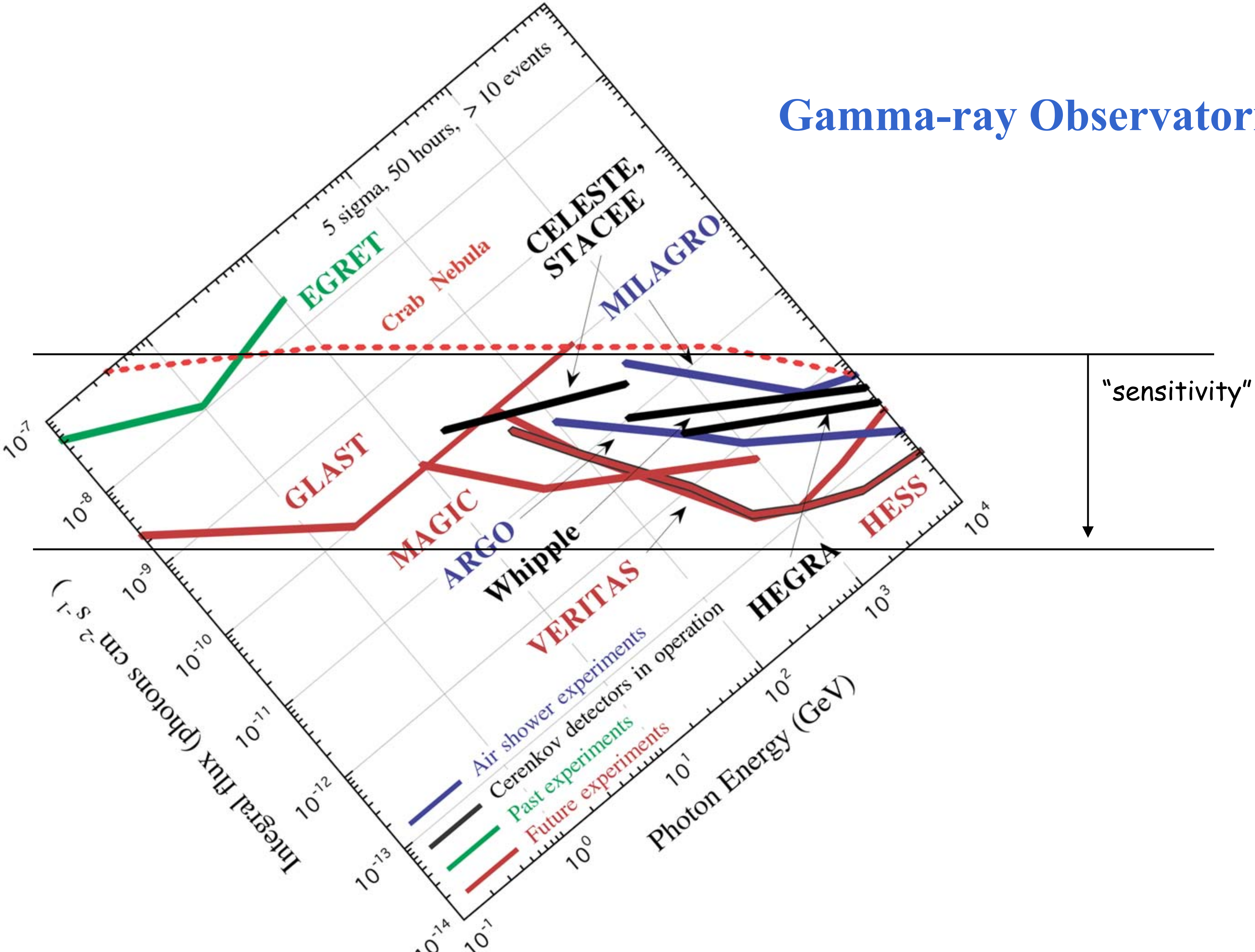


Complementary capabilities

	ground-based		space-based
	ACT	EAS	Pair
angular resolution	good	fair	good
duty cycle	low	high	high
area	large	large	small
field of view	small	large	large+can reorient
energy resolution	good	fair	good, w/ smaller systematic uncertainties
limiting factor	background		photon statistics

The next-generation ground-based and space-based gamma-ray telescopes are well matched.

Gamma-ray Observatories



FUTURE:

GLAST operating plans and prospects for multiwavelength observations.

GLAST Mission Operating Plan

PRELIMINARY!

Important Note

The GLAST operating plans are not firm at this time. Because GLAST is considered a facility, a User's Group is being formed to help advise on the best scientific use of the mission.

Working Concept for GLAST Operations

1. **The first year will be an all-sky survey. Unlike CGRO, the survey will be carried out primarily in a scanning mode, keeping the instruments always pointed away from the Earth (which is bright in gamma rays). This approach takes maximum advantage of the large fields of view of the LAT and the GBM, allowing a full sky survey on short (day) timescales.**
2. **After the first year, the scientific program will be determined by peer-reviewed proposals. Proposals can request pointed observations, based on scientific requirements. A pointed observation can obtain about 3 times as many photons from a source per unit time as the scanning mode. Target of Opportunity proposals can also be included.**

Constraints on GLAST Operations: Essentially none! Any non-occulted source can be observed at any time.

Mission Repointing Plan for Bursts

Summary of plan

During all-sky scanning operations, detection of a sufficiently significant burst will cause the observatory to interrupt the scanning operation autonomously and to remain pointed at the burst region during all non-occulted viewing time for a period of 5 hours (TBR). There are two cases:

1. **The burst occurs within the LAT FOV.** **If the burst is bright enough that an on-board analysis provides >90% certainty that a burst occurred within the LAT FOV, the observatory will slew to keep the burst direction within 30 degrees (TBR) of the LAT z axis during >80% of the entire non-occulted viewing period (neglecting SAA effects). Such events are estimated to occur approximately once per week.**

2. **The burst occurs outside the LAT FOV.** **Only if the burst is exceptionally bright, the observatory will slew to bring the burst direction within 30 degrees (TBR) of the LAT z axis during >80% of the entire non-occulted viewing period (neglecting SAA effects). Such events are likely to occur a few times per year.**

After six months, this strategy will be re-evaluated. In particular, the brightness criterion for case 2 and the stare time will be revisited, based on what has been learned about the late high-energy emission of bursts.

Transients (AGN Flares)

PLAN FOR THE FIRST YEAR

- **Most AGN science can be best addressed by the all-sky scan.**

- **Unusually large flares will be treated as Targets of Opportunity, and studied in a coordinated multiwavelength campaign, for those where a multiwavelength campaign is feasible.**

Thus, autonomous repointing of the spacecraft is not required for AGN science during the first year.

This approach will be re-evaluated after the first year, as new knowledge about AGN might demand a new strategy.

GLAST Mission Data Plans

PRELIMINARY!

Important Note

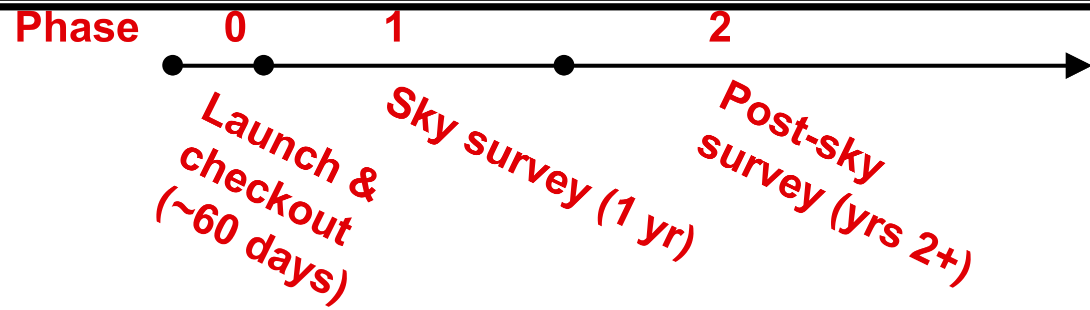
The GLAST data plans are not firm at this time. Because GLAST is considered a facility, a User's Group is being formed to help advise on the best scientific use of the mission.

Working Concept for GLAST Data

1. **During the all-sky survey. The LAT team will use the early data for instrument calibration and preparation of an initial source catalog. At the end of the survey, all the data will be made public. The GLAST Science Support Center will be providing user-friendly software to enable all types of standard analysis.**
2. **After the first year. All data (Level 1 – gamma ray events and sensitivity) will be made public. Guest Investigator proposals will be awarded for scientific ideas, not images or other data. Use of data will be handled on an honor system. No data will be proprietary.**
3. **At all times, data from transient sources, including burst data from the GBM, will be made public immediately, in order to facilitate multiwavelength observations. On-board processing will produce alerts for bursts within seconds.**

DATA RELEASE SCHEDULE

- **Phases of mission**



- **Level 1 data (D1)**
  - **Phase 1 – released by LAT team 30 days after Phase 1 ends; IDSs and ~dozen investigators work with LAT team; data for detected transients released immediately (bursts=transients!)**
  - **Phase 2 – data released as soon as processed; 90 day proprietary period for ‘ideas’ (accepted guest investigator observing/analysis proposals)**
- **Pointing and livetime history (D2) released with the Level 1 data D1**
- **Instrument response functions (D3)**
  - **Initial versions released with the analysis software; updates to be prepared and released as needed (e.g., based on change of instrument response)**
- **Pulsar ephemerides (D4) – primarily radio timing information**
  - **Updated during mission, coordinated by Pulsar Working Group through SSC**
  - **Schedule TBD**
- **LAT source catalog (D5) – released at end of Phase 1, updated at end of 2nd and 5th years (tentative); an ‘early release’ version of the catalog may be made available during Phase 1 to aid proposal preparation**

The GLAST Science Support Center

- To facilitate the multi-mission interpretation of the GLAST data, the GLAST SSC is located in Goddard's Laboratory for High Energy Astrophysics.
- The SSC is responsible for:
  - the guest investigator program
  - the mission timeline (includes support for TOOs, commands)
  - providing data & analysis software to the scientific community
  - archiving data & software in the HEASARC
  - supplying the Italian mirror site with data & software
  - supporting (logistically & scientifically) the Project Scientist, the Science Working Group, and the Users' Committee
  - some data processing (e.g., exposure maps)
- The SSC and the instrument teams will define the analysis software. The instrument teams will manage the software development, but SSC staff will assist.

Challenges for Multiwavelength Observations (1)

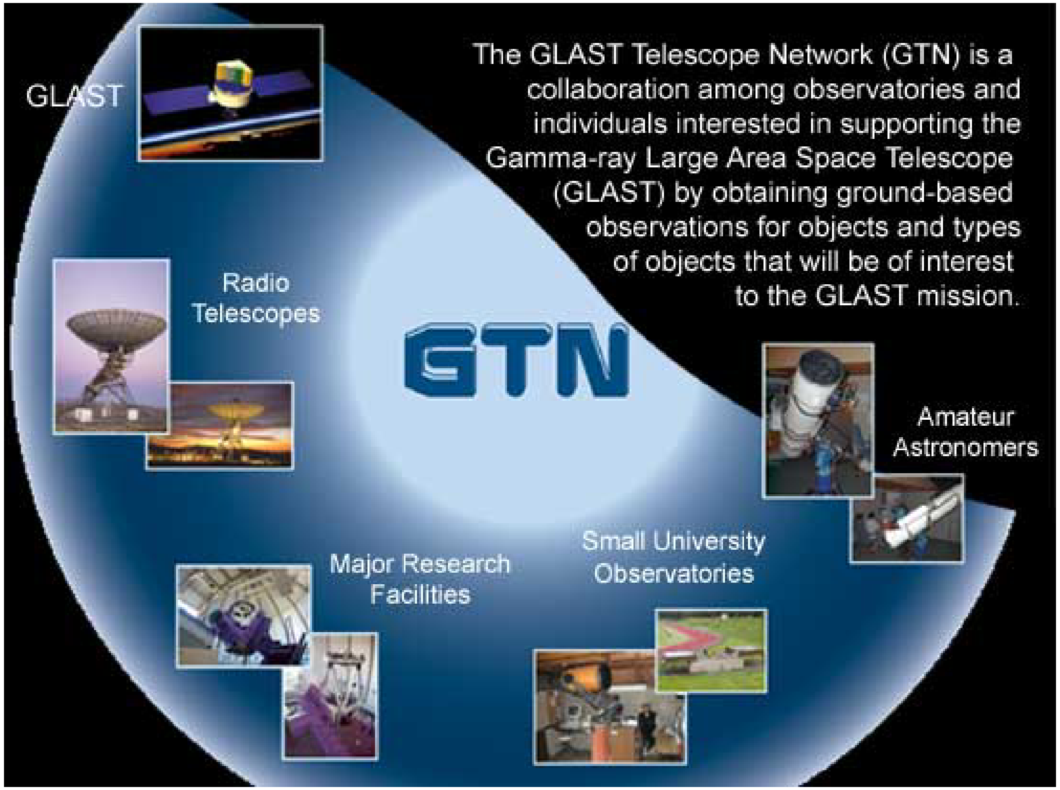
The large GLAST field of view changes the situation, even compared to CGRO

- GLAST can monitor the sky for variable sources.
  - Especially in scanning mode, but even if pointed, GLAST will see a large fraction of the sky with good sensitivity every day. GLAST can serve as a trigger for observations at other wavelengths. Flaring sources probably require some processing on the ground and will require a day or more (depending on intensity) for quicklook recognition. How the GLAST instrument teams communicate this information is under discussion. Proposals include a Web site showing bright sources, updated regularly.
  - Bursts will give an on-board trigger that can be sent immediately to the ground. The current plan is to use the GCN.

Challenges for Multiwavelength Observations (2)

• **Selecting the sources for multiwavelength study will rely largely on other wavelengths.**

- **Availability of telescope time, coordinated plans, and observational constraints will limit the number and choice of sources. The GLAST science teams want to cooperate in multiwavelength programs with the broadest coverage. The LAT team is encouraging small optical observatories and even amateurs to help monitor sufficiently bright sources. We will try to support ongoing programs that contribute to multiwavelength studies.**



The GLAST Telescope Network
http://www-glast.sonoma.edu/gtn/index.html

The Whole Earth Blazar Telescope
http://www.to.astro.it/blazars/webt/homepage.html

The Whole Year Blazar Telescope

Challenges for Multiwavelength Observations (3)

•**We need multiwavelength observation programs even when sources are not flaring**.

- **The broad-band shape of the spectrum is often critical in determining the nature of an unidentified source.**
- **The fluctuation (power density) spectrum is an important part of understanding flares.**
- **Determining blazar radio properties and redshifts is important, since GLAST expects to detect many blazars that are not yet identified as such. The proposed VLBA VIPS program could be extremely valuable.**

Maximizing the science will require cooperation among many instruments at all wavelengths.

Summary

- Multiwavelength observations are essential for GLAST science
  - Both previous observations and theoretical considerations show that gamma-ray sources are usually broad-band objects.
- GLAST will address many important questions:
  - What is going on around black holes? How do Nature's most powerful accelerators work? (are these engines really black holes?)
  - What are the unidentified sources found by EGRET?
  - What is the origin of the diffuse background?
  - What is the high energy behavior of gamma ray bursts?
  - What else out there is shining gamma rays? Are there further surprises in the poorly measured energy region?
  - When did galaxies form?
- GLAST operations will contribute to a wide range of cooperative, multiwavelength observations.

Backup material

Some Lessons Learned from CGRO - AGN (1)

Notes from Bob Hartman

- Even in the optical, it is difficult to get light curves over several weeks for more than 1-3 objects at a time.
- For most blazars, the peak of the synchrotron bump is in the far IR, corresponding to a Compton peak in the GeV range. It would be very useful to be able to correlate those, but there are essentially <u>no observing resources</u> there. We got no real help from ISO.
- Except for the brightest blazars, X-ray observations require focusing instruments. However, the <u>big focusing instruments are generally hugely oversubscribed and very inflexible</u>. We got some good support at times from ASCA, BeppoSAX, and RXTE, but they will probably all be gone by 2007.
- Most of the X-ray telescopes need to have the target near 90 degrees from the Sun. This means that the ground-based observers, (optical, TeV, etc.) must observe in poor conditions, if it is possible at all. Swift may be a big help.
- We had very good radio support from U. Michigan (5, 8, 15 GHz) and Metsahovi (Finland; 22, 37 GHz). However, both of those programs have funding problems. We might be able to influence that (had some success while CGRO was active).

Some Lessons Learned from CGRO - AGN (2)

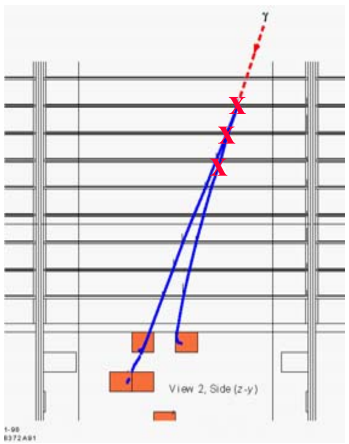
- At higher radio frequencies (90-600 GHz, the instruments are largely dedicated to topics like star formation, etc. We have a few friends in key places, but there is no possibility for monitoring at intervals less than ~1 month.
- The capabilities for VLBI observations at frequencies up to and beyond 100 GHz are improving rapidly. This allows resolution much closer to the nucleus, and better correlation of blob ejections with gamma flares. This will only get better.
- The situation is improving in the optical with the increase in the number of 0.5-1 meter automated telescopes. However, for monitoring bright flares on timescales <1 day, the observers and instruments are largely concentrated in Europe and NA. The Whole Earth Blazar Telescope (WEBT; Mattox; Villata, et al.) is a valuable approach to organizing this.
- For bright objects and flares, the amateur astronomy community can make valuable contributions. With a small amount of financial aid (filters, maybe some CCDs), they could be much more valuable. They are a dedicated bunch - some of them make as many blazar observations as the professionals. The GLAST Telescope Network involves them.

LAT Instrument Triggering and Onboard Data Flow

Level 1 Trigger

Hardware trigger based on special signals from each tower; initiates readout

Function: • "did anything happen?"
• keep as simple as possible



• TKR 3 *x•y* pair planes in a row**

workhorse γ trigger

OR

• CAL:

LO – independent check on TKR trigger.

HI – indicates high energy event → disengage use of ACD.

Upon a L1T, all towers are read out within 20μs

Instrument Total L1T Rate: <4 kHz>

****4 kHz orbit averaged without throttle (1.8 kHz with throttle); peak L1T rate is approximately 13 kHz without throttle and 6 kHz with throttle).**

On-board Processing

full instrument information available to processors.

Function: reduce data to fit within downlink

Hierarchical process: first make the simple selections that require little CPU and data unpacking.

- **subset of full background rejection analysis, with loose cuts**
- **only use quantities that**
  - **are simple and robust**
  - **do not require application of sensor calibration constants**
- **complete event information**
- **signal/bkgd tunable, depending on analysis cuts:**
  γ:cosmic-rays ~ 1:~few

Total L3T Rate: <25-30 Hz>

(average event size: ~8-10 kbits)

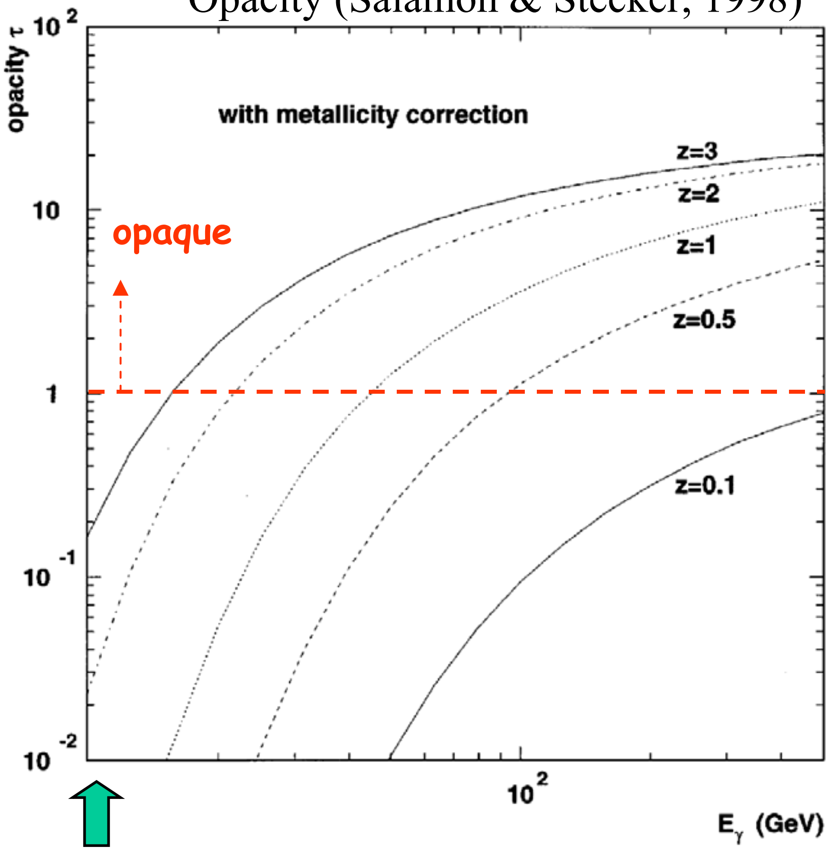
On-board science analysis:
transient detection (AGN flares, bursts)

Spacecraft

An Important Energy Band for Cosmology

Photons with E>10 GeV are attenuated by the diffuse field of UV-Optical-IR extragalactic background light (EBL)

Opacity (Salamon & Stecker, 1998)



No significant attenuation below ~10 GeV.

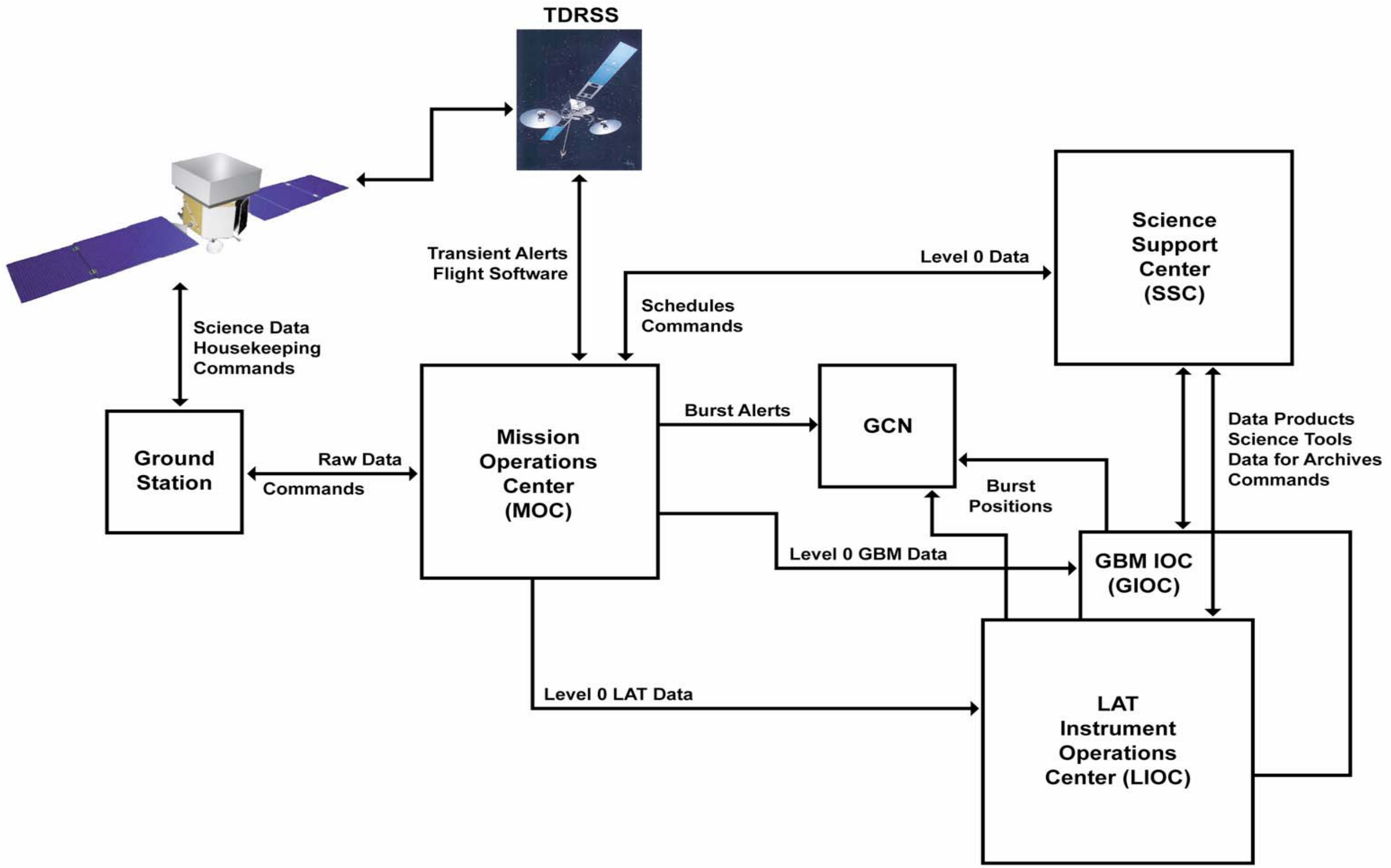
only $e^{-\tau}$ of the original source flux reaches us

EBL over cosmological distances is probed by gammas in the 10-100 GeV range. Important science for GLAST!

In contrast, the TeV-IR attenuation results in a flux that may be limited to more local (or much brighter) sources.

A dominant factor in EBL models is the time of galaxy formation -- attenuation measurements can help distinguish models.

SSC Within Ground System



LAT STANDARD ANALYSIS ENVIRONMENT- INTRODUCTION

- The standard analysis environment consists of the tools and databases needed for routine analysis of LAT data.
- This environment will be used by both the LAT team and the general scientific community.
- This environment was defined jointly by the LAT team and the SSC, but will be developed under the LAT team's management with SSC participation.
- The analysis environment does not support all possible analyses of LAT data. Not included, for example:
  - Analysis of multi-gamma events or cosmic rays
  - High-resolution spectroscopy of extended regions
  - Software for developing the point source catalog

Members of the Science Support Center

The following are present full and part-time SSC members

- Jay Norris—manager
- David Band—science lead
- Dave Davis—databases
- Yasushi Ikebe—calibrations
- Masaharu Hirayama—LAT scientist
- Dirk Petry—user services
- Jim Chiang—ambassador to LIOC
- Valerie Connaughton—GBM scientist, ambassador to GIOC
- Jerry Bonnell—GRBs/PR
- Bob Schaefer—databases
- Cathie Meetre (part time)—operations
- Robin Corbet (part time)—operations
- Sandhia Bansal—programmer
- Chunhui Pan—programmer
- Sandy Barnes—administrator
- JD Myers (part time)—webmaster

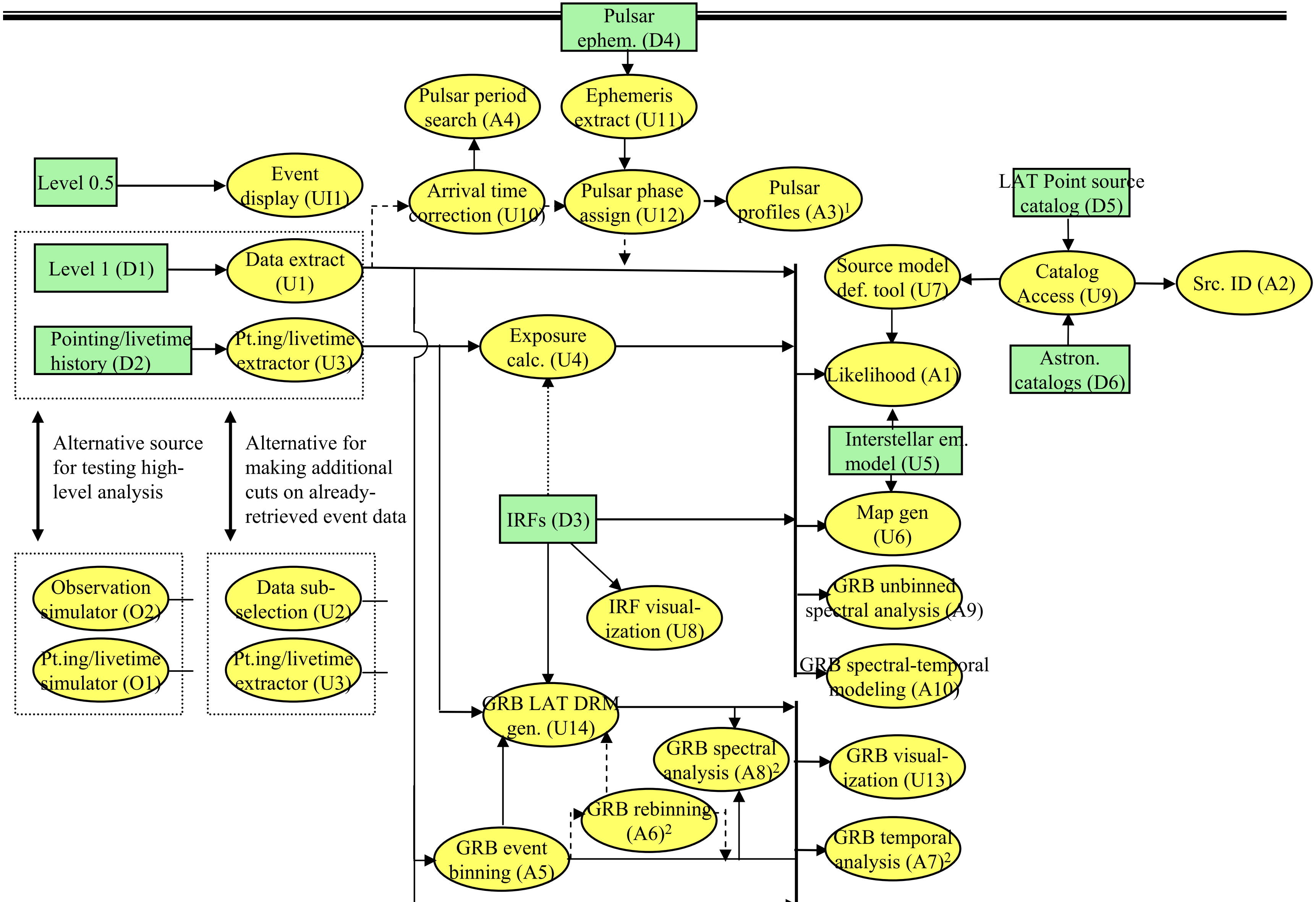
DESIGN CONSIDERATIONS

- The analysis of LAT data will be complex because of:
  - The LAT's large FOV
  - Scanning will be the standard observing mode (photons from a source will be observed with different angles to the detector)
  - A large PSF at low energy
  - A large data space populated by a small number of photons
- The environment will be compatible with HEASARC standards
  - Files will be in FITS format with HEASARC keywords and GLAST extensions
  - Data are extracted by utilities that isolate the analysis tools from databases whose format or architecture may change
  - Data and tools will eventually be transferred to the HEASARC
- Accommodating the user community--the software must be usable by remote investigators with limited institutional knowledge

WALKTHROUGH OF THE STANDARD ANALYSIS ENVIRONMENT

- Schematic illustration of the data flow and how the tools relate to each other. Not all inputs (e.g., from user) are explicitly indicated
  - Detailed descriptions of each component are available
- The tool's identification scheme (letter + number) is for convenience; the distinction between U & A can be subtle
  - D – database (in a general sense)
  - U – utility (supporting analyses)
  - A – analysis tool
  - O – observation simulation
  - UI – user interface (common aspects to utilities & analysis tools)
- Common data types that can pass between tools are defined but not included in the diagram
- User Interface aspects of the SAE--such as Image/plot display, Command line interface & scripting, and GUI & Web access--are not shown explicitly in the diagram

All analysis components together



DEVELOPMENT CONCEPT--SOFTWARE DEVELOPMENT

- The tools will be developed primarily with object-oriented programming using C++.
- Code in other languages will be accepted if robust compilers exist for the supported operating systems and code is supported elsewhere: wrapped into C++ classes
- We will support Windows and Linux.
- We will use the development tools of the LAT instrument simulation:
  - CVS--a code repository with version tracking
  - CMT--build configuration
  - doxygen--documentation
- Class diagrams will be developed for the tools. In addition to structuring the code, these diagrams will identify common classes that can be collected into a GLAST class library.

Sequence of an Analysis: Gamma-Ray Point Source

- Define region of sky, time range, etc. of interest
  - Typical minimum size (based on PSF sizes) radius ~ 15°
- Extract gamma-ray data (U1 accessing D1)
  - Applying selection cuts, including zenith angle
  - Typical data volume (per year): 1×10^6, 10^8 bytes
- Generate exposure (U3 accessing D2)
  - May better be called livetime accumulation
  - Matches cuts applied to gamma-ray data
  - Tabulation ~ $700 \times 15 \times 15 \times 15 \sim 2.5 \times 10^6$ values ~ 10^7 bytes
- Define the model to be fit to the data (U7)
  - Facilitated by candidate source catalog, intensity map and data visualization within U7
  - Models may be considered as a table of parameters, or an XML file, human-readable, including parameters for interstellar emission model
  - Typical region will contain ~dozens of point sources that need to be modelled
- Fit the model to the data, generating, e.g. 'TS maps' and confidence regions (A1) or spectral fits
  - Model may need refinement, iteration within A1